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Auditory and Haptic Feedback in a Socially Assistive Robot Memory Game

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ABSTRACT

Age-related cognitive impairment is becoming a more prevalent concern as the elderly population continues to increase. Technological systems created for cognitive rehabilitation need to be motivating to combat the personal and logistic factors that make it difficult for them to remain engaged [4]. In this paper, we present a pilot study with a socially assistive robot-facilitated memory game that employs sensory feedback (audio, haptic, and both) to explore the design considerations with adults. The ultimate aim is to inform the design of a cognitive rehabilitation system for individuals with age-related cognitive decline. The preliminary results suggest a preference for auditory feedback, and participants believed they performed best in this condition. Based on qualitative feedback, we have identified improvements that can be made to the system to enhance engagement.

KEYWORDS

HRI; Multimodal Feedback System; Socially assistive robot; Age-related cognitive impairment; Cognitive rehabilitation

1 Introduction

The growth rate for older adults has surmounted the world population growth rate, and with this comes the necessity for increased physical and mental care [12]. Age-related cognitive impairment can include symptoms such as difficulty with completing everyday activities, trouble communicating, and memory loss [5]. This can arise directly from ageing or from forms of dementia, such as Alzheimer's Disease [2]. While cognitive rehabilitation has been shown to be effective at treating cognitive impairment [5], logistical considerations such as transportation availability to the clinical facility and high demand on limited staff impedes the potential impact of this therapy [5]. Additionally, individuals may struggle to adhere to the treatments because they may be in denial about their memory condition, have difficulty completing daily tasks, or lack the motivation [4]. Therefore, it is important that any system created for this population is engaging and motivating.

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Socially assistive robots (SAR) have been shown to motivate elderly populations to participate in physical activity [6], and they have also been used to improve cognition. Tapus *et al.* [12] developed a SAR cognitive therapy system that incorporated a music-related task for individuals with dementia that resulted in users displaying prolonged attention, increased accuracy, and decreased reaction time [12]. Another study used reinforcement learning to determine how a SAR should facilitate a card-based memory game for individuals with cognitive impairment [3].

Physical rehabilitation systems that employ sensory feedback, such as SleeveAR for stroke survivors, have been found to be more effective compared to traditional forms of treatment [13]. Both auditory [7] and haptic [9] feedback has been shown to improve performance at a memory task. For a study involving a bingo simulator, employing sonification resulted in improved game accuracy [10]. Even with this knowledge, some participants still preferred the game without sonification. This is an example of where a design choice would have to be made based on the overarching goal of the system: improve performance or create a more enjoyable user experience.

By incorporating the motivational strengths of a socially assistive robot with the accuracy benefits of sensory feedback into a memory game, we will investigate design considerations to inform the development of a system to aid individuals with age-related cognitive impairment. To our knowledge, no study has investigated the role of sensory feedback in a memory game that utilises direct interaction with the SAR for cognitive impairment. This study investigates the following questions:

1. Which feedback modality (auditory, haptic, or auditory and haptic), if any, will increase performance (accuracy score) on a memory task facilitated by a SAR?
2. Which feedback modality do participants prefer?
3. Does the preferred feedback modality correlate with the one that maximizes their performance?

2 Methodology

The SAR-facilitated memory game is played as follows:

1. The SAR (Pepper in this instance) verbally states a random set of body parts from the following five options: left/right hand, left/right feet, and head.
2. The user attempts to touch Pepper's body parts in that order.
3. Repeat steps 1 and 2 until the user makes a mistake.

The difficulty is increased by incrementing the number of body parts the participant must remember. The number of items to remember in a given round remained consistent across all participants and did not exceed 8 body parts.

2.1 Experimental Design

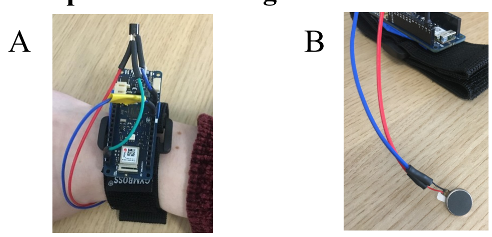

Figure 1: Haptic wearable device that delivers a vibration to the participants wrist. Created from an Arduino MKR WiFi 1010 MCU Module ABX00023 (A) and a vibrating motor (B).

1 *Preliminary Questionnaire* The questionnaire attained basic demographic information, previous technology/robot experience, and whether they have been diagnosed with a hearing or tactile impairment.

2 *Training Period* Pepper instructed the participant on how to touch the head, hands, and feet sensors. Then they were given a practice game that they could repeat as many times as needed until they felt comfortable.

3 *Unimodal and Multimodal Feedback Conditions* During the memory game, feedback is delivered when Pepper is listing each body part and to confirm each body part has been touched (similar to [9]). The conditions were counterbalanced across all participants – see Table 1.

Auditory	A beep was delivered at 800 Hz for 100 ms through Pepper's speakers [11].
Haptic	A vibration cue of 100 ms was delivered on the inside of the wrist (Fig. 1).
Auditory & Haptic	Both the auditory and haptic cues were delivered simultaneously.

Table 1: Feedback Conditions

4 *Evaluation*

Accuracy Score	The total number of correct responses during the memory game.
NASA TLX [8]	The perceived workload of the system for each sensory feedback condition.
SUS [1]	The following adaptation was made: *"this system"* was changed to *"memory game with the (beep/vibration/beep and vibration) feedback"* for each question depending on the condition.

Table 2: Evaluation. The assessments were administered after each experimental condition (Table 1).

2.2 Participants

This pilot study was run with 9 adults without age-related cognitive impairment who were recruited from Heriot-Watt University and the University of Edinburgh (M=25.5 years old, 5 male, 3 female, and 1 preferred not to say). 7 of these participants had past interactions with robots, and no one reported hearing or tactile impairments.

3 Results

In terms of accuracy, a One-Way Repeated Measures ANOVA resulted in no significant difference between the three feedback conditions ($p = 0.99$), with an average score of 18.7 (±12.1). The highest average score for the SUS was auditory (83.3), followed by haptic (78.1) and multimodal (74.7). This may be partially due to the strength of the haptic feedback. The hardware was limited in this regard, whereas it could only output one vibrational strength, and most participants wanted it to be stronger.

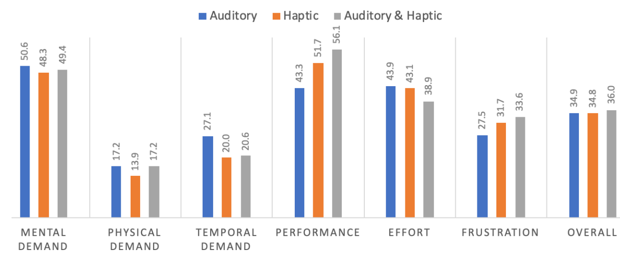

Figure 2: RAW NASA TLX results (100 point scale)

From the NASA TLX (Fig. 2), we can see that the task did not yield high overall workload across all feedback mechanisms. Some participants stated that the beep made them feel rushed, which aligns with auditory having the highest workload compared to the other conditions in the temporal demand category. However, participants felt that they were most successful in performing the task with auditory feedback (Fig. 2, Performance), and this was also the preferred form of feedback.

4 Conclusion

Whereas there was no significant difference in game accuracy, we could not observe differences between preference and performance. However, the NASA TLX scores suggested that participants thought they performed the best with auditory feedback, and the SUS revealed that auditory feedback was most preferred. This system feasibility study has provided insight into future improvements that could be made to the sensory feedback mechanisms to make the memory game more engaging, such as increasing the strength of the haptic feedback to increase the ease with which it is perceived. Future work includes making adjustments and testing the system with older adults to finalise the design before introducing it to older adults with cognitive impairment. Gaining an understanding of how to best design sensory feedback for a SAR assisted memory game can help inform future studies involving age-related cognitive impairment rehabilitation.

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REFERENCES

[1] J. Brooke. “SUS-A quick and dirty usability scale.” *Usability evaluation in industry*, 1996, 189(194), pp.4-7.

[2] B. Chebaa, A. Lioulemes, M. Abujelala, D. Ebert, S. Phan, E. Becker, and F. Makedon. “Multimodal Analysis of Serious Games for Cognitive and Physiological Assessment.” *Proceedings of the 9th ACM International Conference on Pervasive Technologies Related to Assistive Environments - PETRA 16*, 2016.

[3] J. Chan and G. Nejat. “Social Intelligence for a Robot Engaging People in Cognitive Training Activities,” *International Journal of Advanced Robotic Systems*, 2012, 9(4), pp. 113.

[4] J. Choi, and E.W. Twamley. “Cognitive rehabilitation therapies for Alzheimer’s disease: A review of methods to improve treatment engagement and self-efficacy,” *Neuropsychology Review*, 2013, pp. 48–62.

[5] A. L. Faria and S.B.I. Badia. “Development and evaluation of a web-based cognitive task generator for personalized cognitive training: a proof of concept study with stroke patients,” *Proceedings of the 3rd 2015 Workshop on ICTs for Improving Patients Rehabilitation Research Techniques - REHAB 15*, 2015.

[6] J. Fasola and M. J. Matarić. “Robot exercise instructor: A socially assistive robot system to monitor and encourage physical exercise for the elderly.” *Proc. - IEEE Int. Work. Robot Hum. Interact. Commun.*, 2010, pp. 416–421.

[7] S. Finney and C. Palmer. “Auditory feedback and memory for music performance: Sound evidence for an encoding effect,” *Memory & Cognition*, 2003, 31(1), pp. 51–64.

[8] S.G. Hart, and L.E. Staveland. “Development of NASA-TLX (Task Load Index): Results of Empirical and Theoretical Research.” 1988.

[9] S. Kuznetsov, A. K. Dey, and S. E. Hudson. “The Effectiveness of Haptic Cues as an Assistive Technology for Human Memory,” *Proceedings of the 6th International Conference on Foundations of Digital Games - FDG 11*, 2009.

[10] D. Ramos and E. Folmer. “Supplemental Sonification of a Bingo Game.” *FDG ’11 Proceedings of the 6th International Conference on Foundations of Digital Games*, 2011, pp. 168–173.

[11] G. Rosati, F. Oscari, D.J. Reinkensmeyer, R. Secoli, F. Avanzini, S. Spagnol, and S. Masiero. “Improving robotics for neurorehabilitation: Enhancing engagement, performance, and learning with auditory feedback.” *2011 IEEE International Conference on Rehabilitation Robotics,* 2011.

[12] A. Tapus, C. Tapus, and M.J. Mataric. “The use of socially assistive robots in the design of intelligent cognitive therapies for people with dementia.” *2009 IEEE International Conference on Rehabilitation Robotics,* 2009.

[13] J. Vieira, M. Sousa, A. Arsénio, and J. Jorge. “Augmented Reality for Rehabilitation Using Multimodal Feedback.” *Proceedings of the 3rd 2015 Workshop on ICTs for Improving Patients Rehabilitation Research Techniques - REHAB 15,* 2015.